# Measurement of Wet Antenna Effect On Microwave Propagation at 23, 26 and 38 GHz

*M.R. Islam & A. R. Tharek*
*Wireless Communication Research Lab*
*University of Technology Malaysia*
*Skudai, 81310 J.B, Fax: 607-556-6272*
*E-mail: rafiq@nadi.fke.utm.my*

## ABSTRACT

Losses due to water being in or on the surface of the radomes or the parabolic reflector and on the feed window of antennas are occurred during rain. An experiment has been done to measure the losses on the antennas due to rain by spraying water. In order to separate this loss from the propagation loss, an analytical approach has been proposed. A physical model for wet antenna loss has been developed based on measured one year rain attenuation and rainfall statistics in Malaysian tropical climate.

## INTRODUCTION

Affect of rain on radome surface or on the parabolic reflector and on the feed window is considerable at higher frequencies. It depends on antenna geometry, elevation angle, rain rate etc (Rudge, 1983). Recent studies show that this loss is significant for the measurement of excess attenuation due to rain (Hogg 1977, Siller 1979, Fenn 1997, Chebil 1997, Crane 1998, Acosta 1999 & Ong 1999 ). No physical or theoretical antenna wetting models are available at present for terrestrial line-of-sight links at 23 GHz to 38 GHz frequency range. Three experimental MINI-LINKS at 23, 26 and 38 GHz were installed at UTM Skudai for the measurement of attenuation due to rain in Malaysia. Wet antenna losses are required to be subtracted from the measured attenuation in order to get the propagation losses accurately. Since the path length is very short (0.3 km), this loss contributes a significant part of the measured rain attenuation.

An attempt to measure these losses was conducted and the results are presented in this paper. An analytical approach has been proposed and a physical model has been developed based on one-year measured rain attenuation at 23 GHz, 26 GHz and 38 GHz and corresponding measured rainfall statistics by using this approach.

## WATER SPRAY TEST

A series of water spray tests have been performed on three antennas installed at the roof of the Wireless Communication Research Lab (WCRL) in UTM Skudai Campus. The diameter of all antennas are 0.6 m and the operating frequencies are 23, 26 and 38 GHz. Two antennas are covered by radomes (26 and 38 GHz) and the rest one is exposed to atmosphere. All antennas are parabolic in shape and are functioning as the receiver of a 300 m LOS terrestrial link. The water spraying test has been done by controlling the nozzle position of the hose pipe. A water vessel having capacity of 1200 Gal was brought to the nearest position of the antennas. A 4.5 H.P. motor pumped water to antenna position which is about 10 m above the ground level. In order to increase the water pressure at nozzle, the Hose pipe has been staged in three steps with Diameter of 2 inches, 1½ inches and 1 inch from motor up to the end. The water has been sprayed for

0-7803-6369-8/00/$10.00 ©2000 IEEE

several times and each time, the spray duration time varied from 3 to 5 minutes. The heavy spray was managed for few times only.

Errors may be introduced in few test events due to change in wind direction and velocity, variations in the motor speed and human error for holding and maintaining the nozzle position and direction during the spray test. The attenuation has been sampled and recorded in 1 sample/sec. The water spray recorded in rain gauge and the corresponding averaged wet antenna losses can be observed in Fig. 1. The loss occurred at 23 GHz is higher than that of 26 GHz for lower spray rate but it drops by much amount at heavier spray rate. This might be due to the accumulation of water at the feed window of 23 GHz uncovered antenna at lower spray rate and the same phenomenon continued to exist at heavier rate also. The losses at all antennas increased gradually with heavier water spray and increased to as much as 8.0 dB for 38 GHz, 7.0 dB for 26 GHz and 5.0 dB for 23 GHz when heavy water was sprayed from the front on the antenna surfaces.

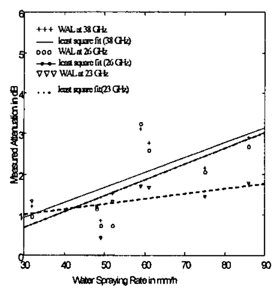

**Fig. 1.** Wet Antenna Losses measured during water spray test at WCRL.

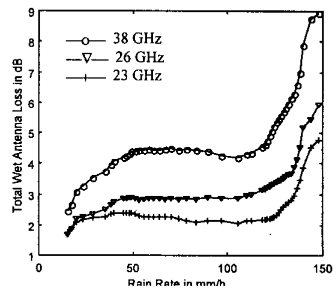


**Fig. 2.** Variations of total wet antenna loss with rain rate measured in UTM Skudai from July 1 1998 to June 30 1999.

This situation can be considered similar to the model developed by ACTS propagation experiment at NASA (Crane, 1998). The losses proposed by the model are about 7.0 dB for 27.5 GHz and 6.0 dB for 20.2 GHz antennas at 100 mm/h rain rate. Both antennas of the model were faced to satellite with about $50^0$ elevation angle. Therefore, the loss measured by spray test which was conducted here and directly on the antenna surfaces can be compared with the loss encountered by the model at 100 mm/h rain rate.

By close and careful observation during raining event, a combination of water droplets, water rivulets and water sheeting had been found on the surface of radomes at 26 and 38 GHz. Therefore the radomes can be considered as having non-hydrophobic surface.

## ANALYTICAL APPROACH

Let the wet antenna losses is a function of frequency, structure and materials of the radomes(if the antenna is covered by radomes) or the structure and materials used for the antenna reflector and the feed (if the antenna is exposed to atmosphere) and rainfall rate measured on the antenna.

Therefore, wet antenna losses can be approximated as follows

$$A_W = A(F,L,R,W) \tag{1}$$

Where, F is the operating frequency

L is the parameter accounts for structure and materials concerned

R is the measured rain rate in mm/h

W is the pattern of wetting phenomenon

For any line-of-sight terrestrial microwave link, if the pair of antennas used for transmit and receive purposes are similar in construction and having the same materials, the losses contributed by it would be constant. Hence the wet antenna losses can be expressed as a function of rainfall rate and wetting pattern only and the equation(1) can be reduced as

$$A_W = A(R_x, W_i) + A_C \tag{2}$$

Where $A_C$ = constant part of the wet antenna losses

$R_x = R_1, R_2, R_3, \ldots\ldots$ mm/h

$W_i = W_1$ for water droplets on the surface

$W_2$ for water rivulets on the surface

$W_3$ for water sheet on the surface

$W_4$ for other wetting conditions

Since the non-linear relationship between rain rate and propagation loss due to rain has been adopted globally by ITU-R, the measured rain rate for any particular frequency can be expressed by the following equation

$$\begin{aligned} A_x &= A_P + A_W \\ &= 0.3\, a\, R_x^{\,b} + A(R_x) + A_C \end{aligned} \tag{3}$$

where $A_x$ is the measured rain attenuation in dB for rain rate of x mm/h

$A_P$ is the rain caused attenuation during propagation for 300 m path lenth

$A_W$ is the wet antenna losses encountered for both antennas

For the rain rate of x1,x2,x3,x4,......., the equation (3) can be expanded as

$$A_{x1} = 0.3\, a\, R_{x1}^{\,b} + A(R_{x1}) + A_C \tag{4}$$

$$A_{x2} = 0.3\, a\, R_{x2}^{\,b} + A(R_{x2}) + A_C \tag{5}$$

...

$$A_{x(n-1)} = 0.3\, a\, R_{x(n-1)}^{\,b} + A(R_{x(n-1)}) + A_C \tag{6}$$

$$A_{xn} = 0.3\, a\, R_{xn}^{\,b} + A(R_{xn}) + A_C \tag{7}$$

$$A_{x(n+1)} = 0.3\, a\, R_{x(n+1)}^{\,b} + A(R_{x(n+1)}) + A_C \tag{8}$$

...

If we subtract equation (4) from (5), (6) from (7) and so on, the following results can be obtained

$$A_{x2} - A_{x1} = 0.3\, a\, (R_{x2}^{\,b} - R_{x1}^{\,b}) + A(R_{x2}) - A(R_{x1})$$

$$A_{x3} - A_{x2} = 0.3\, a\, (R_{x3}^{\,b} - R_{x2}^{\,b}) + A(R_{x3}) - A(R_{x2})$$

...

$$A_{xn} - A_{x(n-1)} = 0.3\, a\, (R_{xn}^{\,b} - R_{x(n-1)}^{\,b}) + A(R_{xn}) - A(R_{x(n-1)}) \tag{9}$$

If uniform difference between two consecutive rain rates is $\Delta x$ and then $\Delta x$ can be expressed as

$$x2-x1 = x3-x2 = x4-x3 = xn-x(n-1) = \Delta x \tag{10}$$

Now, the increment $\Delta x$ can have any values from 1 mm/h to higher. For very short range of increment values within a specified wetting conditions, the wet antenna losses given in equations (9) can be assumed constant and can be cancelled it out from the equations set.

$$A(R_{x2}) - A(R_{x1}) = A(R_{x3}) - A(R_{x2}) = A(R_{xn}) - A(R_{x(n-1)}) = 0 \qquad (11)$$

Therefore, the equations set shown in (9) can be expressed as the terms of propagation loss only and can be re-written as

$$\begin{aligned} A_{x2} - A_{x1} &= 0.3\, a\,(R_{x2}^{\,b} - R_{x1}^{\,b}) \\ A_{x3} - A_{x2} &= 0.3\, a\,(R_{x3}^{\,b} - R_{x2}^{\,b}) \\ &\dots \\ A_{xn} - A_{x(n-1)} &= 0.3\, a\,(R_{xn}^{\,b} - R_{x(n-1)}^{\,b}) \end{aligned} \qquad (12)$$

For rain rate measured over one year period (July 1 1998 – June 30 1999) and corresponding measured rain attenuation at 38, 26, 23 and 15 GHz for the same period, we have constructed four sets of equations as shown in (12). The value for the rain rate increment $\Delta x$ was chosen as 2 mm/h for solving the parameters $a$ and $b$ in (12). The nonlinear set of equations have been solved by least square methods. The algorithm used is the Gauss-Newton method with a mixed quadratic and cubic line search procedure from Matlab optimization toolbox. The results obtained are shown in Fig. 2.

The wet antenna loss shown in Fig. 1, is the loss measured in one antenna of the MINI-LINK, whilst Fig. 2 encountered the loss in both antennas. It is obvious that the loss calculated from statistical data is similar with the spray test. The wet antenna loss is clearly dependent on frequency and higher frequency suffers more. In Fig. 2, the loss increases sharply for rain rate higher than 130 mm/h. By close and careful investigation during several raining event, a combination of water droplets and water rivulets on the surface of antenna and radomes had been observed for medium rainfall and water sheeting for heavy raining time. Water sheeting may cause sharp changes of wet antenna loss during higher rainfall rate. It might be supported and understood by comparing measured rain attenuation at these frequencies and those proposed by ITU-R and are given in Fig. 3. to Fig. 5.

## CONCLUSIONS

Measurement by water spray test can give an idea of the wet antenna losses occurred during rain. Since, we are not able to simulate the real rain, the measured values are inadequate to figure out the actual wet antenna losses. Weathering effects degrade the hydrophobic surface resulting in degradation of wet loss with time. The direction of wind also plays an important role during rain. Therefore, the proposed approach for the estimation of the wet antenna losses from measured rain attenuation statistics can give more accurate results.

## REFERENCES

Acosta J. Roberto (1999), "Wet Antenna Effect on Ka-Band Low Margin Systems", Commission F,National Radio Science Meeting (URSI), Orlando, July 11-16, 1999.

Chebil J., (1997), "Rain Rate and Rain Attenuation Distribution For Microwave Propagation Study in Malaysia", Ph.D. Thesis, Faculty of Electrical Engineering, University of Technology Malaysia (UTM), 1997.

Crane R.K. and D.V. Rogers, (1998), "Review of the Advanced Communications Technology Satellite (ACTS) Propagation Campaign in North America", IEEE Antennas and Propagation Magazine, Vol. 40, No. 6, December 1998.
Fenn A.J., (1997) "Measurements of Wet Radome Transmission Loss and Deplorization Effects in Simulated Rain at 20 GHz", 10th International Conference on Antennas and Propagation, 14-17 April, Conference Publications No. 436, IEE, 1997.
Hogg D.C. , A.J. Giger, A.C. Longton, and E.E. Muller (1977), "The Influence of Rain on Design of 11-GHz Terrestrial Radio Relay", The Bell System Technical Journal, Vol. 56, Number 9, pp. 1575-1580, November 1977.
Ong, J.T., Emily Choo, G. Liu and C.G. Teo (1999), "Rain Attenuation and other Effects on a Short 38 GHz Line-of-sight Link", 2nd Int. Conf. On Communications (ICICS'99), Singapore, December 7-10, 1999.
Rudge A.W., K.Milne, A.D. Olver and P. Knight (1983), "The Handbook of Antenna Design", Volume 2, Peter Peregrinus (on behalf of IEE), pp. 538-541, 1983.
Siller C.A., JR., (1979), "Preliminary Testing of Teflon as a Hydrophobic Coating for Microwave Radomes", IEEE Transactions on Antennas and Propagation, vol. AP-27, No. 4, July 1979.

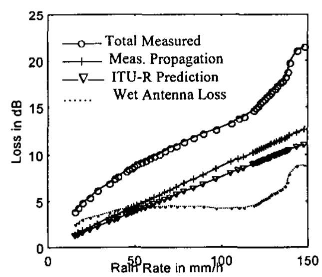


**Fig. 3**. Measured one-year data at 38 GHz for 0.30 km. path length.

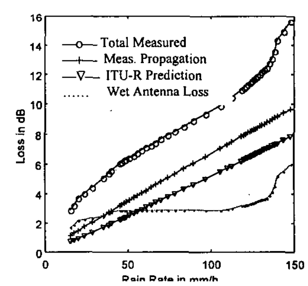


**Fig. 4**. Measured one-year data at 26 GHz for 0.30 km. path length.

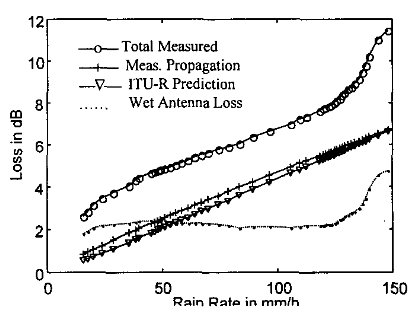


**Fig. 5**. Measured one-year data at 23 GHz for 0.30 km. path length.